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A NEW OCCURRENCE OF CRISTOBALITE IN CALIFORNIA

AUSTIN F. ROGERS
Stanford University, California

Cristobalite, one of the rarer high-temperature forms of silica, was first described from the andesite of Cerro San Cristobal, near Pachuca, Mexico, by vom Rath,¹ and was established as a distinct mineral species by Mallard.² Artificial cristobalite has been prepared in the Geophysical Laboratory at Washington and its properties and its relation to the other forms of silica have been studied by Fenner.³ Silica bricks are made up of artificial cristobalite and tridymite, and so these minerals are of some importance to the metallurgist.

The work of the Geophysical Laboratory is extremely valuable, but of especial interest to the mineralogist and petrographer is the actual occurrence of these minerals in nature. The laboratory production of such artificial minerals is largely to aid in the interpretation of natural occurrences. Cristobalite has been known from five or six foreign localities for some time and in 1918 the writer⁴ described it from two American localities, both in California. Since that time he has obtained specimens from five additional American localities.

The cristobalite described in this paper, like the Yellowstone Park occurrence recently described,⁵ is found in a rhyolitic obsidian. The exact locality of the specimens could not be ascertained. The material was placed in the writer's hands by Mr. R. M. Wilke, mineral dealer of Palo Alto, California. Mr. Wilke obtained the specimens from a prospector, who would not divulge the locality. Mr. Wilke, however, says "I am sure the place is somewhere in the

¹ *Neues Jahrb. Min.* (1887), pp. 1, 198.

² *Bull. Soc. Min. France*, Vol. XIII (1890), p. 172.

³ *Amer. Jour. Sci.* (4), Vol. XXXVI (1913), pp. 331-84.

⁴ *Ibid.*, XLV, pp. 222-26.

⁵ *Amer. Mineralogist*, Vol. VI (1921), pp. 4-6.

northwest corner of San Bernardino County, to the northwest of Barstow, probably within 40 to 50 miles from Barstow." The geological map of California compiled by Professor James Perrin Smith and published by the California State Mining Bureau shows a number of outcrops of volcanic rocks northwest of Barstow, and so Mr. Wilke is probably correct as to the approximate locality.

THE OBSIDIAN AND ITS LITHOPHYSAE

The specimens consist of dark gray to almost black obsidian ($n = 1.483 \pm .003$) with a faint banded structure and bright vitreous luster. In thin fragments the obsidian shows on microscopic examination numerous, minute, rod-shaped crystallites arranged in parallel lines and a few microlites.

The obsidian contains many light gray spherulites which range from 5 to 25 mm. in diameter and are fairly evenly distributed, though sometimes two of them coalesce. The spherulites are more or less flattened; some of them are elongate, and most of them are somewhat irregular in outline. With a few exceptions they are hollow and hence may be called lithophysae. It is estimated that the spherulitic material occupies only about a fifth to a half of the original space. The spherulites are for the most part ruptured, and deep cracks extend almost to their margin, so that the spaces left are usually very irregular in outline. The cracks give some of the lithophysae a superficial resemblance to mud-cracks. The thickness of the spherulitic material is often only about a tenth of the radius of the original cavity.

Accompanying the obsidian specimens were a number of loose spherulites or lithophysae, which had been broken out of the obsidian. They are much more regular than the imbedded lithophysae just described. One of these is shown in the photographic enlargement (Fig. 1). They have a more or less well-defined hollow space at the center and show a slight tendency to concentric structure, as may be noticed in the photograph.

It seems probable that both the expansive force of the gas within the cavity and the tension due to cooling of the surrounding glass were responsible for the formation of the lithophysae.¹

¹ For a discussion of the origin of lithophysae, see paper by Wright, *Bull. Geol. Soc. Am.*, Vol. XXVI (1915), pp. 255-86.

MINERALS OF THE SPHERULITES

The solid portions of the spherulites consist of two minerals, orthoclase and cristobalite, and of these orthoclase predominates. The orthoclase and cristobalite occur in fibrous aggregates, which on microscopic examination prove to be intergrowths. In spots, which are probably cross-sections, they have an intricate interlocking structure which suggests graphic texture. The orthoclase is

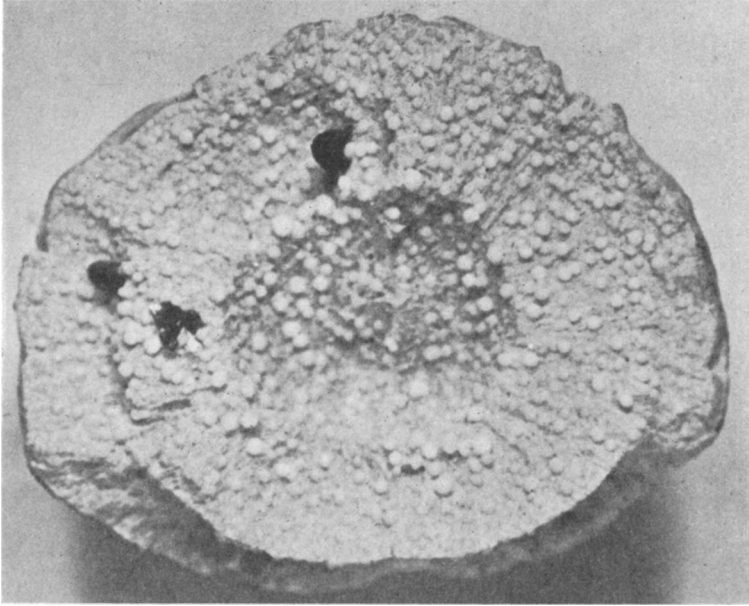


FIG. 1.—($\times 5$) Cristobalite and Fayalite in a Lithophysa of the Obsidian from San Bernardino County, California.

cloudy, while the cristobalite is clear. The cristobalite is identified by its index of refraction, which is slightly greater than 1.480. Most of the cristobalite areas are isotropic, but occasionally they show very weak double refraction. The double refraction is uniform, which distinguishes the cristobalite from the glass which has practically the same index of refraction.

It seems probable from the descriptions in the literature that such orthoclase-cristobalite spherulites are characteristic of rhyo-

litic obsidians, but have not been recognized before on account of the difficulty of distinguishing the cristobalite. It was with great difficulty that the writer succeeded in proving that the mineral intergrown with the orthoclase was cristobalite.

Imbedded in these larger spherulites are numerous, very minute, spherical bodies, which consist largely of orthoclase with small amounts of cristobalite. These probably represent earlier formed spherulites of orthoclase which have been recrystallized during the later main period of spherulite production. Such composite spherulites have been described by Rutley¹ from another locality in California. Rutley speaks of "isotropic matter" between the rods or fibers of orthoclase, which in all probability is cristobalite.

There is a little magnetite imbedded in the spherulitic material.

MINERALS OF THE LITHOPHYSAL CAVITIES

The following minerals were identified in the lithophysae: orthoclase, cristobalite, tridymite, opal, magnetite, and fayalite. These minerals occur on the walls of the lithophysal cavities and the specimens make beautiful microscopic mounts (Fig. 1).

Orthoclase.—On the free surface of the cavities the orthoclase takes on the form of branching rods with weak birefringence and positive elongation (parallel to γ). The index of refraction is $1.517 \pm .003$.

Cristobalite.—The cristobalite occurs in minute (0.2–0.5 mm.) translucent white spherulites, which are scattered over the surface of the lithophysae as illustrated in the photograph. In fragments the cristobalite shows a well-defined spherulitic structure with elongation of the crystals parallel to the faster ray a . There is intricate polysynthetic twinning and the extinction is oblique. The double refraction is very weak.

The index of refraction of the cristobalite is $1.483 \pm .003$, which was determined by means of immersion liquids. This determination positively distinguishes it from tridymite which has indices of refraction of 1.469–1.473.

The specific gravity of the cristobalite is $2.36 \pm .04$, which was determined by means of a mixture of acetylene tetrabromid and

¹ *Quar. Jour. Geol. Soc.*, Vol. XLVI (1890), pp. 423–28.

benzol. (It sank in the liquid in which gypsum [sp. gr. = 2.32] remained suspended and floated in the liquid in which brucite [sp. gr. = 2.39] remained suspended.)

In still another respect did the mineral agree with cristobalite. It is infusible and on heating to a high temperature by means of a blowpipe it became semi-transparent and on cooling it suddenly became translucent again. This sudden change in appearance, which may serve as a blowpipe test for cristobalite, is due to the conversion of the high-temperature β -cristobalite to the low-temperature α -cristobalite, which, according to Fenner, takes place in artificial cristobalite at a temperature varying from 198 to 240° C.

Tridymite.—The exterior of most of the cristobalite spherulites when examined with a high-power binocular microscope are seen to be studded with very minute six-sided crystals of tabular habit. These are identified as tridymite by their index of refraction, $n = 1.475 \pm .005$. The tridymite is transparent in contrast to the translucent cristobalite. Some of minute cristobalite spherulites apparently are converted into tridymite, but careful microscopic examination shows that the cristobalite is simply covered with the tridymite.

Opal.—Several of the lithophysal cavities are coated with a thin layer of hyalite opal (n slightly less than 1.45), which was evidently the last mineral formed. No chalcedony or quartz could be detected in any of the specimens.

Fayalite.—A few, small (1 mm.), brown, transparent crystals of fayalite (Fe_2SiO_4) are found on the free surfaces of the lithophysae. Three crystals (dark areas) are shown in the photograph. They are tabular in habit and resemble the fayalite from the spherulitic obsidian of Yellowstone National Park. The fayalite has an index of refraction greater than 1.74 and gives an iron borax bead test. Some of the crystals have been altered to a black opaque substance.

Magnetite.—Very minute octahedral crystals of magnetite are visible with the high-power microscope.

FORMATION OF THE MINERALS

The minerals lining the walls of the lithophysae evidently were formed by hot gases liberated by the crystallization of the spheru-

lites. The orthoclase and cristobalite are largely products of recrystallization of the spherulites. The cristobalite probably was formed at a comparatively high temperature and as the temperature became lower, tridymite was formed, and at about the same time fayalite and magnetite appeared. The opal is the only mineral that was formed by ordinary solutions. The oxidation of the fayalite, a slight staining of the lithophysae, and whitening of the orthoclase rods are the result of weathering.

CRISTOBALITE IN SPHERULITIC OBSIDIAN

The Yellowstone Park occurrence, the San Bernardino County occurrence of the present paper, and two undescribed Californian occurrences, all taken together, point to the conclusion that cristobalite is one of the characteristic minerals of spherulitic obsidian. In fact it seems to be more common in such rocks than tridymite. It is probable that in some cases cristobalite has been identified incorrectly as tridymite. For example the minute pellets referred to and figured by Iddings¹ in the spherulitic obsidian of Yellowstone Park are probably cristobalite instead of tridymite.

¹ *Seventh Ann. Rept. U.S. Geol. Survey* (1888), p. 264, Pl. 12, Fig. 3.